



Information Requirements for Supervisory Air Traffic Controllers in Support of a Mid-Term Wake Vortex Departure System

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TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS.....	2
LIST OF FIGURES.....	3
1.0 BACKGROUND.....	5
2.0 INTRODUCTION.....	6
3.0 OBJECTIVE AND APPROACH.....	6
4.0 WTMD OVERVIEW.....	7
5.0 DATA COLLECTION LOCATIONS.....	10
5.1 STL WTMD SYSTEM INSTALLATION.....	10
5.2 STL OPERATIONAL ENVIRONMENT.....	11
5.3 IAH WTMD SYSTEM INSTALLATION.....	11
5.4 IAH OPERATIONAL ENVIRONMENT.....	11
6.0 DATA COLLECTION AND STUDY SUBJECTS.....	11
6.1 GENERAL OVERVIEW OF ACTIVITY.....	11
6.2 STUDY SUBJECTS.....	11
6.3 TRAINING AND TEST PROCEDURE.....	12
6.5 DATA COLLECTION.....	12
6.5.1. Data collected.....	12
6.5.2 Data collection environment.....	12
7.0 RESULTS.....	12
7.1 SUBJECT ATC EXPERIENCE.....	13
7.2 QUESTIONNAIRE QUANTITATIVE RESULTS.....	13
7.3 GENERAL COMMENTS FROM SUBJECTS.....	18
8.0 CONCLUDING REMARKS.....	20
9.0 REFERENCES.....	21
APPENDIX A - STL WTMD SYSTEM INSTALLATION.....	22
APPENDIX B - AIRPORT DIAGRAM – LAMBERT-ST. LOUIS INTERNATIONAL AIRPORT (STL)	23
APPENDIX C - IAH WTMD SYSTEM INSTALLATION.....	24
APPENDIX D - AIRPORT DIAGRAM – GEORGE BUSH INTERCONTINENTAL/ HOUSTON AIRPORT	25
APPENDIX E - SAMPLE SCENARIO.....	26
APPENDIX F - POST SCENARIO INTERVIEW GUIDE.....	28
APPENDIX G - QUESTIONNAIRE.....	30

Abbreviations and Acronyms

AAR	Airport Arrival Rate
ACE-IDS	ASOS Controller Equipment - Information Display System
AGL	above ground level
ASDE	Airport Surface Detection Equipment
ASOS	Automated Surface Observation System
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATCT	Airport Traffic Control Tower
ATIS	Automatic Terminal Information Service
CAASD	Center for Advanced Aviation System Development
CSPR	Closely Spaced Parallel Runway
D-BRITE	Digital Bright Radar Indicator Tower Equipment
ESRL	Earth System Research Lab
FAA	Federal Aviation Administration
HITL	Human-In-The-Loop
IAH	George Bush Intercontinental/Houston Airport
IDS4	Information Display System
ITWS	Integrated Terminal Weather System
MIT	Massachusetts Institute of Technology
MIT LL	MIT Lincoln Laboratory
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NEXRAD	Next Generation Radar
RBDT	Ribbon Display Terminal
RUC	Rapid Update Cycle
STL	Lambert-St. Louis International Airport
TDWR	Terminal Doppler Weather Radar
TRACON	Terminal Radar Approach Control
VMC	visual meteorological conditions
WSR	Weather Surveillance Radar
WTMD	Wake Turbulence Mitigation for Departures

List of Figures

Figure 1. WTMD Wind Condition	7
Figure 2. WTMD System	8
Figure 3. WTMD System Status Display	9
Figure 4. WTMD System Status Display with “WTMD ON”	9
Figure 5. WTMD System Status Display with “Alert”	10
Figure 6. (a) Ability to Obtain Information Related to the WTMD Procedure, (b) Confidence in Having Access to Information, and (c) Confidence in the Decision to Enable/Authorize and Disable/Terminate WTMD Procedure	14
Figure 7. Anticipated Helpfulness of the History of the Status of the WTMD Procedure	15
Figure 8. Displays Supervisors Normally Look At (a) Most Likely with an Enable WTMD Procedure and (b) with No WTMD Procedure.....	15
Figure 9. Display Perceived Effectiveness in Deciding to (a) Enable/Authorize or (b) Disable/Terminate WTMD Procedure	16
Figure 10. Supervisors’ Anticipated Requirements for Monitoring WTMD Information With and Without WTMD Authorized	16
Figure 11. Ease of Determining Appropriate Runway on which to Enable WTMD Procedure On	17
Figure 12. Perceived Effectiveness of WTMD Procedure During Low and Sustained Departure Demand.....	17
Figure A.1 Overview of STL WTMD Network Architecture	22
Figure A.2 STL WTMD Prototype Hardware	22
Figure B.1 Airport Diagram – Lambert-St. Louis International Airport	23
Figure C.1 Overview of IAH WTMD Network Architecture	24
Figure C.2 IAH WTMD Shadow Mode Field Prototype Architecture	24
Figure D.1 Airport Diagram – George Bush Intercontinental/Houston Airport	25
Figure E.1 IAH WTMD Status Display	26
Figure E.2 IAH Sample ASDE	27

Abstract

Closely Spaced Parallel Runway (CSPR) configurations are capacity limited for departures due to the requirement to apply wake vortex separation standards from traffic departing on the adjacent parallel runway. To mitigate the effects of this constraint, a concept focusing on wind dependent departure operations has been developed known as the Wake Turbulence Mitigation for Departures (WTMD). This concept takes advantage of the fact that crosswinds of sufficient velocity blow wakes generated by aircraft departing from the downwind runway away from the upwind runway. Consequently, under certain conditions, wake separations on the upwind runway would not be required based on wakes generated by aircraft on the downwind runway as is currently the case. It follows that information requirements, and sources for this information, would need to be determined for airport traffic control tower (ATCT) supervisory personnel who would be charged with decisions regarding use of the procedure. To determine the information requirements, data were collected from ATCT supervisors and controller-in-charge qualified individuals at Lambert-St. Louis International Airport (STL) and George Bush Houston Intercontinental Airport (IAH). STL and IAH were chosen as data collection sites based on the implementation of a WTMD prototype system, operating in shadow mode, at these locations. The 17 total subjects (STL: 5, IAH: 12) represented a broad-base of air traffic experience. Results indicated that the following information was required to support the conduct of WTMD operations: current and forecast weather information, current and forecast traffic demand and traffic flow restrictions, and WTMD System status information and alerting. Subjects further indicated that the requisite information is currently available in the tower cab with the exception of the WTMD status and alerting. Subjects were given a demonstration of a display supporting the prototype systems and unanimously stated that the WTMD status information they felt important was represented. Overwhelmingly, subjects felt that approving, monitoring and terminating the WTMD procedure could be integrated into their supervisory workload.

1.0 Background

Current Air Traffic Control (ATC) procedures require additional separation between aircraft arriving or departing in trail of certain aircraft categories out of consideration for the effects of wake turbulence; these standards are contained in the ATC Handbook (Ref. 1). Controllers apply these standards regardless of weather conditions unless the requirements for visual separation are met and appropriate procedures are applied. In many cases, this results in overly-conservative (excessive) spacing compared to what is required to avoid the wake hazard. The adverse effects on airport capacity and, hence, the National Airspace System (NAS) resulting from the applications of current wake turbulence separation standards are well documented. Efforts have been underway for many years to improve understanding of the wake vortex phenomenon and to characterize the associated hazards. This knowledge may permit reduced separation behind wake generating aircraft and improved capacity (Ref. 2). The FAA and NASA have collaborated to address airport capacity constraints related to wake turbulence avoidance and mitigation

procedures, and to research, develop, and implement a time-phased series of enhancements in airport arrival and departure operations. Three implementation periods have been defined to guide the process: near-term Phase I (2006 – 2008), mid-term Phase II (2011 – 2013), and far-term Phase III (2014+). The focus of work described in this document falls into the mid-term, Phase II category; specifically, work in the area of departure operations.

2.0 Introduction

A concept focusing on wind-dependent departure operations has been developed (Ref. 3). The current version of this concept is called the Wake Turbulence Mitigation for Departures (WTMD). This concept would be applied to operations at airports with closely spaced parallel runways (CSPR), and takes advantage of the fact that cross winds of sufficient velocity blow wakes generated by “heavy” and B757 category aircraft on the downwind runway away from the upwind runway (Fig. 1). This means that departures on the upwind runway are not affected by wakes generated on the downwind runway, therefore wake separation of upwind runway departure traffic from traffic on the downwind runway is not required. Wake standards would still have to be applied between consecutive departures from the same runway and for departures from the downwind runway following departures from the upwind runway.

This concept has been refined and evaluated in two Human-In-The-Loop (HITL) simulations conducted at MITRE’s Center for Advanced Aviation System Development (CAASD) simulation facility using the Lambert-St. Louis International Airport (STL) as the operational environment. The objectives of the first simulation were to determine requirements for full-up evaluations of CSPR departure procedures and to evaluate simulation characteristics and fidelity. The results indicated that the simulation was deemed satisfactory, and that the procedure appeared to be operationally feasible (Ref. 4). The second HITL simulation focused on the WTMD procedure usability, workload, and information requirements for the local controllers and supervisor, and display information requirements. Controllers found that using the WTMD procedures was relatively easy, with workload remaining within acceptable limits. Further, the prototype interface provided adequate information to accomplish responsibilities with respect to the procedure. Finally, departure rate improvements were observed when WTMD operations were in effect (Ref. 5).

The next logical step in the evaluation of the WTMD procedure was a set of field deployments to candidate airports to determine the engineering feasibility of the WTMD system. In conjunction with the engineering feasibility studies, a supervisory assessment was conducted to determine the information requirements of airport traffic control tower supervisors and to validate the controller assessment simulation results.

3.0 Objective and Approach

The objective of the information requirements assessment documented here was to understand the supervisory controller decision-making process, information requirements, and information sources for authorizing, conducting, and terminating the WTMD procedure. During the data collection sessions, it became clear that comments received from subjects would not be limited to those which addressed the study objectives. These additional comments are also documented in this report.

To meet the research objectives, data were collected from supervisor and controller-in-charge personnel at both the Lambert-St. Louis International Airport (STL) and George Bush Intercontinental/Houston Airport (IAH) Airport Traffic Control Tower (ATCT) facilities. (Note that when the term “supervisor” is used in this document, it includes the controller-in-charge function.) Data collection sessions were conducted at the respective facilities in administrative spaces. Specific details of the data collection sessions are provided in Section 5.

4.0 WTMD Overview

The WTMD concept (Ref. 3) improves the efficiency of CSPR¹ operations by allowing upwind runway departures to be released independently of Heavy/B-757 aircraft operating on the downwind runway (Ref. 2). Current wake separation standards do not account for crosswind transport of wakes and therefore require additional spacing beyond standard separation requirements (Ref. 1). As an improved operational procedure, WTMD would be authorized only when wind conditions exist that prevent the transport of wakes from a downwind runway to an adjacent parallel runway (Fig. 1).

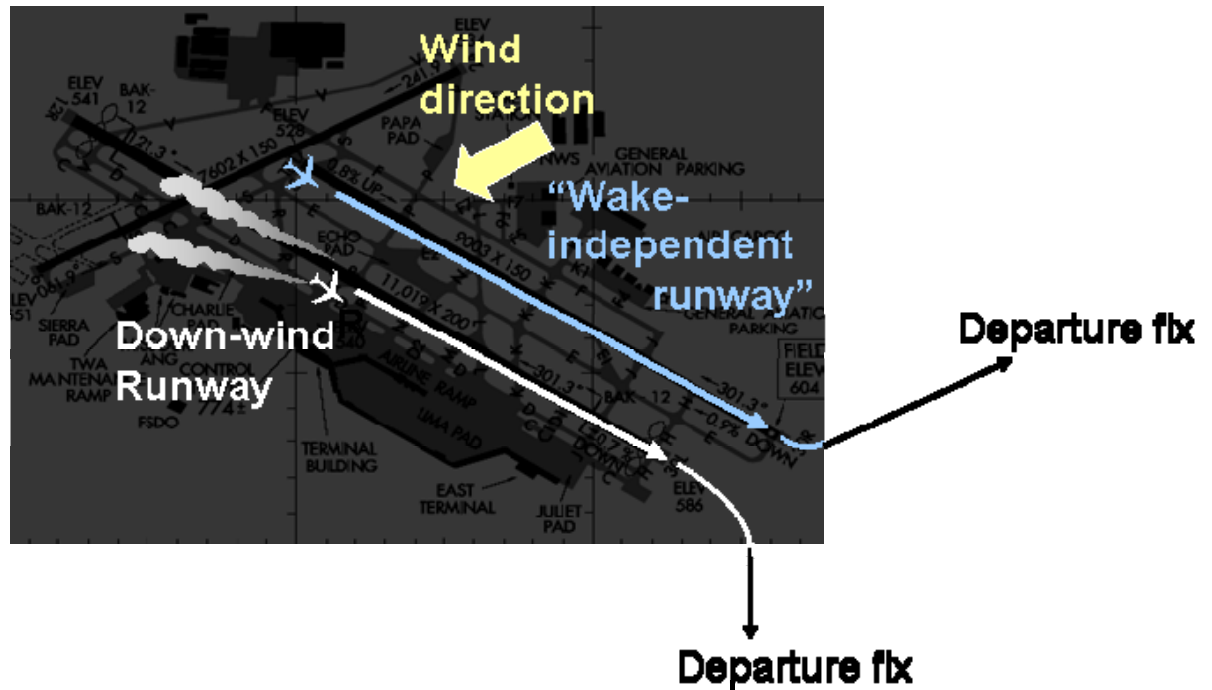


Figure 1. WTMD Wind Condition

Specifically, when the crosswind component is three knots² or greater away from the trailing departure on a parallel runway, the procedure can be used. Departures may then be released from the “wake independent runway” without regard to wake turbulence generated from Heavy/B-757 aircraft departing on the down-wind runway. This condition is verified through a wind forecast algorithm that incorporates current airfield wind and Rapid Update Cycle (RUC) forecast winds from the surface through 1000’ above ground level (AGL). This resulting wind forecast volume contains the parallel runway departure paths up to the altitude at which diverging headings are initiated. If the wind forecast algorithm indicates the WTMD system is available, the ATCT supervisor may enable the system. The WTMD procedure is then

¹ CSPRs are defined as those with less than 2500’ between runway centerlines.

² Below three knots, airfield wind measurements are unreliable in both magnitude and direction.

put into effect, and the upwind runway becomes wake-independent. When the wind condition changes to a non-favorable cross-wind, the WTMD procedure must be terminated and dependent CSPR separation standards are then applied.

The ATCT supervisor is responsible for the activation, monitoring and termination of the WTMD procedure, while the ATCT local controller is responsible for implementing separation standards for the departure runways. Certain facilities may use two or more controllers to manage these runways, depending on their operation, e.g., dual use with arrivals or as dedicated departure runways.

Simplicity was the guiding principal in the development of the WTMD concept, so a simple “On or Off” procedure was developed in concert with a prototype WTMD status indication and alerting system/display (Fig. 2).

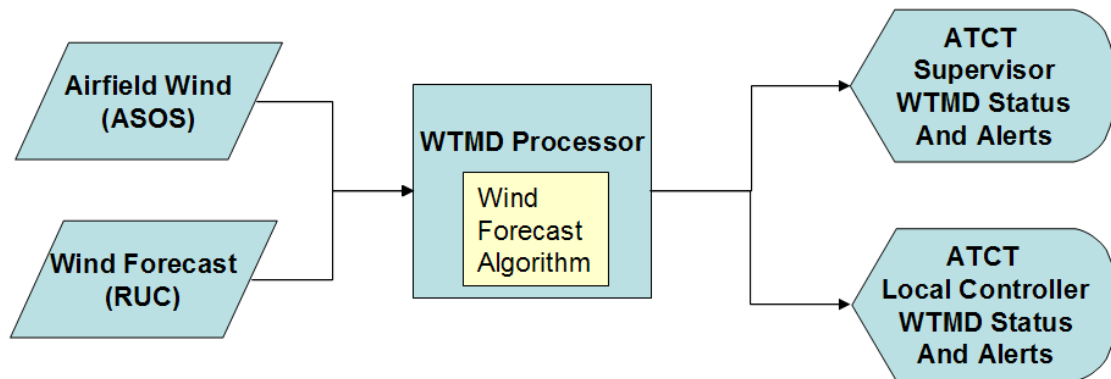


Figure 2. WTMD System

To ensure that the WTMD procedure can be conducted safely, two features have been incorporated into the wind forecast algorithm: 1) the wind predictions that enable use of this procedure will be valid for at least 20 minutes, and 2) the prediction incorporates a three-minute guarantee; simply, at any given time, the winds will support use of the WTMD procedure for a minimum of three minutes. This permits the safe execution of any clearances issued should the WTMD system change status from “WTMD On” to “WTMD Off.” Tools, in the form of prototype displays supporting the WTMD procedure were developed for the local controller assessment (Ref. 5) and more recently, in support of field implementations of the WTMD system and the supervisor assessment. These displays were, by design simple, intending to convey the necessary information required to support the WTMD procedure (Figs. 3-5). The following definitions correspond to the displays.

Available means the WTMD procedure could be enabled for use on a particular runway.

Off means the WTMD procedure is not available for use on a particular runway.

Enable means the WTMD procedure could be approved for use for a particular runway.

Disable means the WTMD procedure could be stopped for a particular runway.

Status means the state of the WTMD procedure; operational, failed, available, off, and runway with the enabled WTMD procedure.

The system state, as shown in Figure 3, can be “initializing” when the system is booting up; “operational” (as depicted here) when the system is functioning; or “fault” when the system has a problem, (e.g., sensor or communications malfunction), and is not functioning properly. Also depicted are the runway status

(“Available” or “OFF”) and the interface (“Enable”) button to turn WTMD on for a runway.



Figure 3. WTMD System Status Display

Once the supervisor enables one of the runways, the runway status indicator shows “WTMD ON” for that runway and other runway options are either “OFF” or “Available” as depicted in Figure 4.



Figure 4. WTMD System Status Display with “WTMD ON”

Figure 5 shows the change in runway status to “Alert,” which was accompanied by a “WTMD OFF” audio alert. When the system is operational, this alerting occurs when the wind condition no longer supports WTMD operations and the WTMD operation must be terminated.



Figure 5. WTMD System Status Display with “Alert”

One possible implementation of a WTMD display that could be implemented for the tower controllers is described in Reference 5. However, no decision has been reached on the particular implementation of operational displays, and additional research is required. The final implementation will depend on local automation architectures, which vary from airport to airport.

5.0 Data Collection Locations

Two air traffic facilities were used for the information requirements data collection: STL and IAH. These facilities were selected based on the implementation of WTMD systems at these locations. The following sections describe the implementation of the WTMD systems and include a brief operational overview of the respective locations. The prototype WTMD system architecture was used for demonstration of the engineering feasibility of the WTMD system and for identifying system requirements.

5.1 STL WTMD System Installation

The WTMD system was run in receive-only or “shadow-mode,” as follows: The WTMD system was connected to the ACE-IDS test unit and was configured to display simple WTMD status information on a non-operational page, accessible only on the test unit in an administrative space of the STL control tower. The ACE-IDS configuration used the standard ACE-IDS interface for a Ribbon Display Terminal (RBDT). The ACE-IDS test unit was then connected to the live STL ACE-IDS network. An overview of the network architecture for the STL WTMD prototype is depicted in Figure A.1.

For the WTMD prototype system, the MIT Lincoln Laboratory (MIT-LL) served as the data integrator and supplier of data to the STL prototype site. MIT-LL received 1-minute ASOS data from STL through the FAA Technical Center and 1-hr Rapid Update Cycle (RUC) wind forecasts from the National Centers for Environmental Prediction (NCEP). MIT-LL also received Terminal Doppler Weather Radar (TDWR) from STL using a dedicated frame-relay and NEXRAD data from NCEP. MIT-LL created a data message containing 1-minute ASOS data and RUC data from forecast grid locations closest to STL and sent it to the WTMD core computer at the STL prototype site through the internet. No other data was sent to the field WTMD prototype installation from MIT-LL.

The WTMD shadow-mode field prototype architecture is presented in Figure A.2. The prototype architecture used two independent computers. One computer served as the ACE-IDS platform and the second hosted the WTMD prototype.

5.2 STL Operational Environment

The STL airport diagram is provided in Appendix B. Of particular interest for the application of the WTMD operations are runways 12L and 30R and 12R and 30L. These CSPRs have thresholds sufficiently staggered on either end that a 3 minute departure delay is required for traffic departing on the runway with the staggered threshold downfield (along the centerline axis) from the adjacent parallel runway threshold. This rule applies when the stagger is 500' or greater. Techniques are used by controllers to minimize the effect of this requirement; however, removing the "dependency" through the application of WTMD would benefit the overall operation and provide flexibility.

5.3 IAH WTMD System Installation

The IAH WTMD system was also run in a shadow-mode to investigate the engineering feasibility and air traffic controller acceptability of hosting the WTMD controller displays on a Systems Atlanta Information Display System (IDS4) platform. The IDS4 test unit was installed and configured by Systems Atlanta, Inc. An overview of the network architecture for the WTMD prototype is depicted in Figure C.1. The WTMD shadow-mode field prototype architecture is represented in Figure C.2. The prototype architecture used two independent computers. One computer was the IDS4 platform and the second hosted all other functions of the WTMD prototype.

5.4 IAH Operational Environment

The airport diagram for IAH is provided in Appendix D. The primary departure runways at IAH are 15L and 15R. They are CSPRs and are commonly used as dedicated departure runways. Runways 33L and 33R are also of interest as the thresholds are sufficiently staggered (applying the 500 ft rule) such that the 3 minute departure delay for wake turbulence is required.

6.0 Data Collection and Study Subjects

6.1 General Overview of Activity

The focus of the data collection activity with respect to the roles and decision-making process in implementing the WTMD procedure was on the supervisor position in the ATCT. The role of the supervisor with respect to the WTMD procedure is relatively simple: approve the use of, monitor as required, or terminate use of, the WTMD procedure. The process by which these decisions are reached may not be as simple and could vary significantly between individuals and between airports. Additional related decisions required of the supervisor included selection of, and changes to, runway configurations and arrival and departure procedures based on traffic demand and weather. With this in mind, the goal of the data collection effort was to understand how the supervisor arrives at a decision with respect to WTMD operations, what information is required, and the sources of that information.

6.2 Study Subjects

Study subjects were supervisory air traffic controllers and controllers that are controller-in-charge qualified. Facility management was briefed on the WTMD concept, study objectives and process, and coordinated participation for all subjects. Seventeen subjects participated in the data collection activity - 5 from STL and 12 from IAH. The backgrounds of the seventeen subjects represented extensive and broad based experience in the ATC arena (see Section 7.1).

6.3 Training and Test Procedure

The WTMD concept is, by design, relatively simple. It follows that the tools and procedures are simple and straightforward so the time required for training is minimal. Training was accomplished through presentation of power point slides and hard copy briefing materials. This activity was conducted in one-on-one sessions.

The following test procedure applied to subjects. Data collection sessions began with a briefing focusing on the WTMD procedure, the role of the supervisor and local controller with respect to the procedure, and the WTMD display. The briefing was interactive and subjects were encouraged to ask questions as required to ensure an understanding of the concept. After the briefing, the applicability of the procedure to the subject's particular operation (i.e. STL or IAH) was discussed. It was readily apparent based on these discussions that all subjects sufficiently understood the concept from the briefing. Subjects were provided with a demonstration of the shadow-mode WTMD system followed by a discussion of the WTMD display. Subjects were then presented with three scenarios representing different operational conditions (sample in Appendix E). The purpose of the scenarios was to provide a context for use of the WTMD procedure. The primary variables in the scenarios were weather conditions and traffic loading (current and projected). The scenarios all assumed that factors such as ATCT staffing and supervisor workload were within acceptable bounds to consider authorization of the procedure. Based on the scenarios, subjects were asked to respond with comments regarding the methodology in determining whether they would approve WTMD operations and to discuss the factors involved in reaching their decisions. Note that the emphasis was in determining the decision making process (including information requirements and sources), not whether or not they would have authorized the procedure under the conditions presented. However, some factors (such as flow restrictions at departure fixes) were introduced in the scenarios to determine if this might affect the decision to authorize the procedure. The final part of data collection was the administration of a questionnaire and subsequent concluding interview.

6.5 Data Collection

6.5.1. Data collected

Feedback was obtained by questionnaire and comments derived from general discussions and follow-up interviews. Comments were captured throughout the data collection session using a voice recorder. Following the presentation of each scenario, the subjects would comment on what information was important and how they would go about making a decision to authorize the procedure. A structured interview guide was used to ensure basic subject areas were addressed (Appendix F). Following a demonstration of the shadow-mode system, comments were gathered concerning the status and alerting information. As the final activity in the data collection session, the subjects completed the questionnaire (Appendix G). After the questionnaire was completed, the researcher reviewed it with the subject to determine if any responses required clarification.

6.5.2 Data collection environment

The location for the prototype system and data collection were administrative office spaces, separate from the ATCT control room.

7.0 Results

Results indicated that the following information was required to support the conduct of WTMD operations: current and forecast weather information, current and forecast traffic demand and traffic flow restrictions, and WTMD System status information and alerting. Amplification on these requirements as well as others is provided in the following three sections. The first section addresses the subjects' ATC experience and

the following two sections discuss questionnaire quantitative results and comments offered by the subjects, respectively.

7.1 Subject ATC Experience

The seventeen subjects represented an extensive and broad base of experience in air traffic operations. Air traffic qualifications across the subjects included certifications for ATCT facilities, TRACONs, and Centers. Additional experience included staff members from both the Operations as well as Support Specialists. Determining the level of ATCT experience for the IAH subjects was complicated by the fact that it was a “combined facility” until 1993. This meant controllers worked both the ATCT as well as the TRACON. Supervisors continued to work both facilities until 2004, at which time the supervisory functions at these facilities were also divided. Personal preferences also played a part in the experience they had accumulated in the ATCT or TRACON. To account for the uncertainties introduced by these conditions, a conservative estimate of ATCT experience was used.

The average number of years ATC experience across the 17 subjects by facility type was as follows:

Average total years of ATC experience: 26.35

Average years ATCT experience: 16.23

Average years TRACON experience: 9.11

7.2 Questionnaire Quantitative Results

The supervisor questionnaire to assess the WTMD procedure is available in Appendix G. The following were defined in the questionnaire.

Operational means the WTMD system is receiving valid data.

Failed means the WTMD system is not receiving valid data.

Available means the WTMD procedure could be enabled for use on a particular runway.

Off means the WTMD procedure is not available for use on a particular runway.

Enable means the WTMD procedure could be approved for use for a particular runway.

Disable means the WTMD procedure could be stopped for a particular runway.

Authorized for use means the supervisor has approved the use of the WTMD procedure.

Terminated the use of means the supervisor has ended the use of the WTMD procedure.

Status means the state of the WTMD procedure; operational, failed, available, off, and runway with the enabled WTMD procedure.

The questionnaire nominal data were analyzed using χ^2 (Chi-squared) tests with significance set at $p \leq 0.05$. The calculated confidence interval for the 95% confidence level and the 17 subjects is 23.8%.

There were no significant differences in responses between subjects from STL and IAH. Consequently, data from the two facilities were combined for the subsequent analyses.

Among the 17 subjects, 12 strongly agreed and five agreed that the training provided on the WTMD procedure was adequate (Appendix G – question 1). Therefore, the following results are predicated on the subjects understanding both the WTMD procedure and its related displays.

Information Availability

Subjects reported that obtaining information about whether to enable and authorize the WTMD procedure or to disable and terminate the WTMD procedure would be easy and they were confident they would have access to the appropriate information to make these decisions (Appendix G – questions 9, 10, 17, and 18) (Fig. 6). They also felt confident that they would be able to enable/authorize or disable/terminate the WTMD procedure with the information given (Appendix G – questions 13 and 19) (Fig. 6).

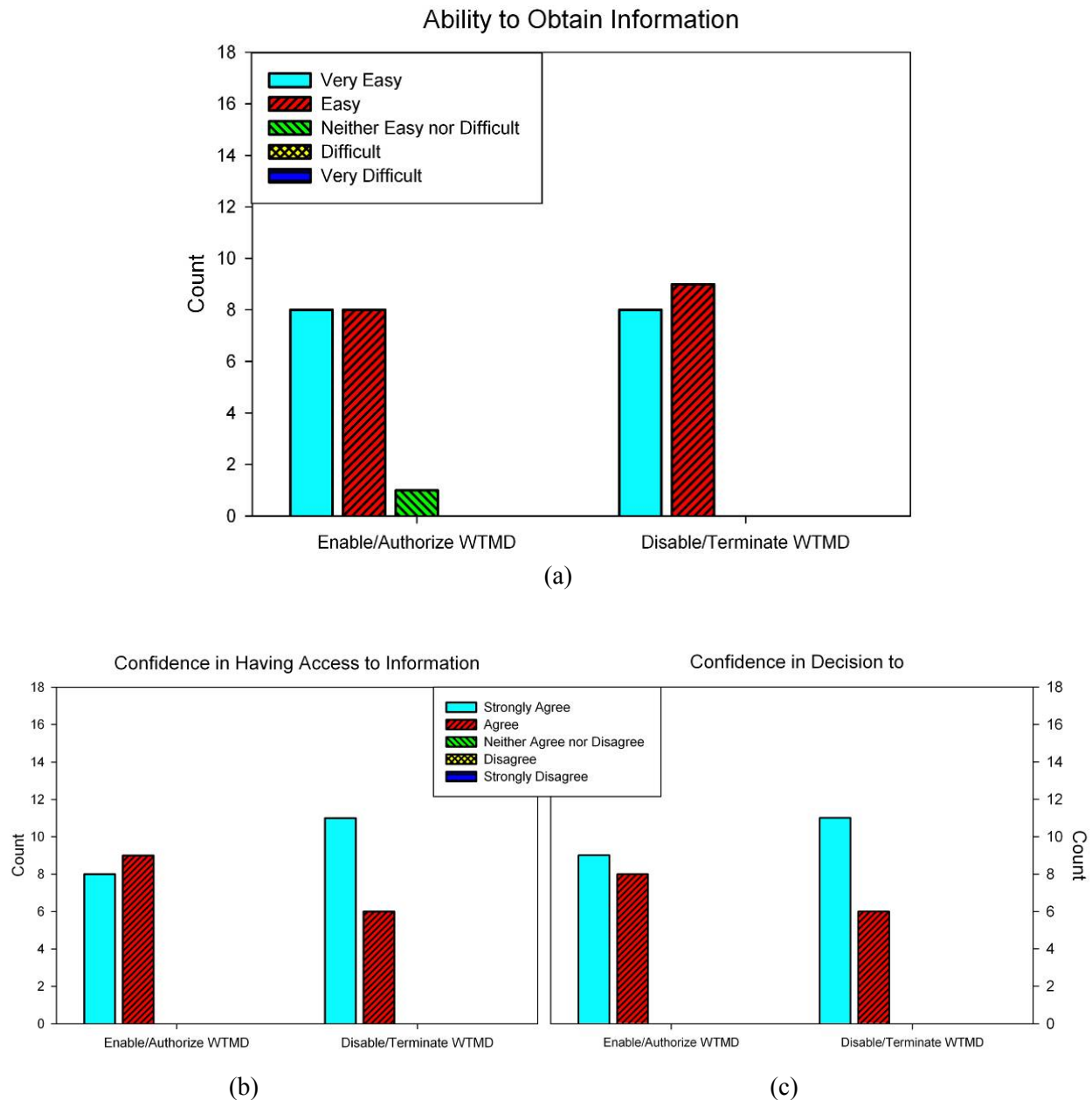


Figure 6. (a) Ability to Obtain Information Related to the WTMD Procedure, (b) Confidence in Having Access to Information, and (c) Confidence in the Decision to Enable/Authorize and Disable/Terminate WTMD Procedure

Of the 17 subjects surveyed, seven strongly agreed and 10 agreed that the information needed to determine the status of the WTMD procedure was sufficient (Appendix G – question 4). Even though the subjects deemed that the provided information relating to the WTMD procedure was sufficient, they also indicated

that they would like to have the history of the status of the WTMD procedure (Fig. 7). Thirteen of the 17 subjects surveyed said this history would affect their willingness to enable and authorize the WTMD procedure (Appendix G – question 12). Thirteen of the 17 subjects also would like to know why the WTMD procedure became unavailable (Appendix G – question 21).

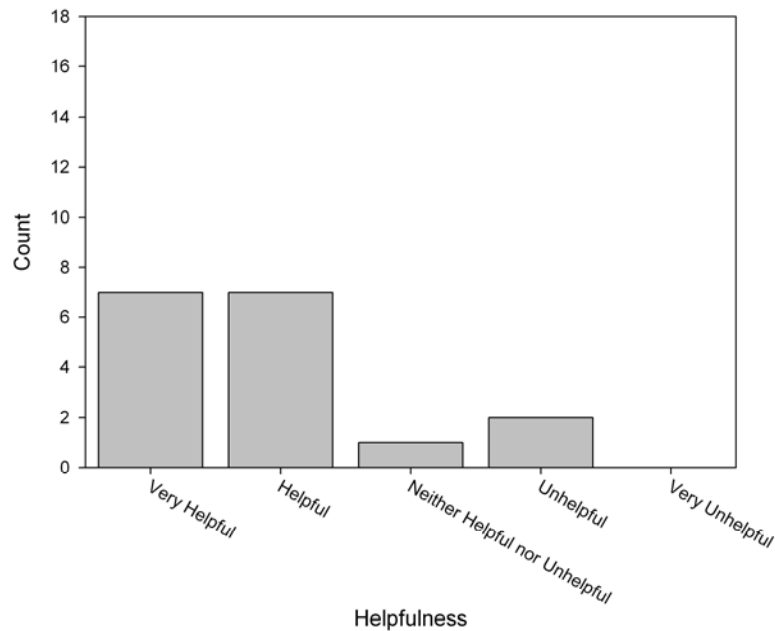


Figure 7. Anticipated Helpfulness of the History of the Status of the WTMD Procedure

Information Placement

The subjects reported that they frequently look at the D-BRITE and ASDE displays for information (Appendix G – question 2) (Fig. 8). With an Enabled WTMD procedure, supervisors stated they would not significantly change the displays they look at when compared to No WTMD procedure (Appendix G – question 3).

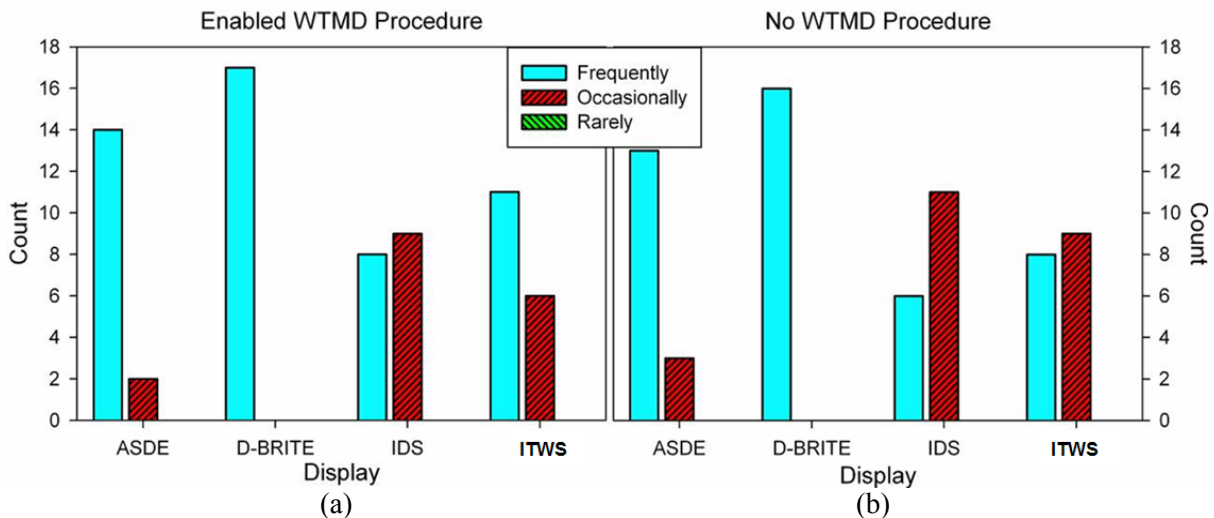


Figure 8. Displays Supervisors Normally Look At (a) Most Likely with an Enable WTMD Procedure and (b) with No WTMD Procedure

Subjects indicated that the displays they normally look at would also be helpful, in addition to the WTMD system state display, in enabling/authorizing or disabling/terminating the WTMD procedure (Appendix G – questions 16 and 22) (Fig.9). Supervisors judged that the ITWS display was the most effective for deciding to enable/authorize and disable/terminate the WTMD procedure. Supervisors did feel they would have to monitor the status of the WTMD procedure and its availability at least occasionally, whether or not it was active (authorized) (Appendix G – questions 5 and 6) (Fig. 10).

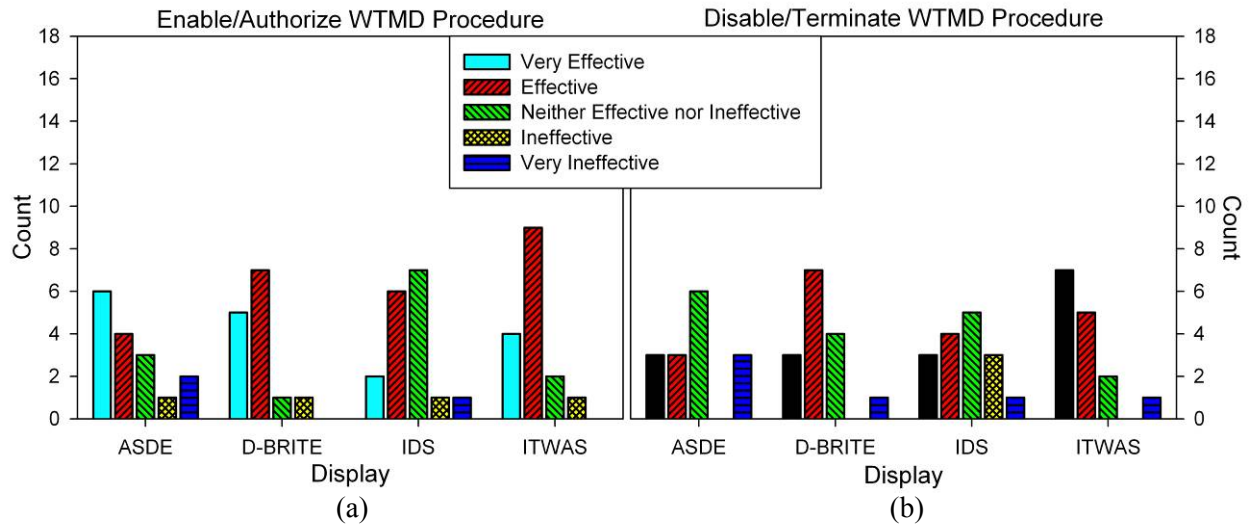


Figure 9. Display Perceived Effectiveness in Deciding to (a) Enable/Authorize or (b) Disable/Terminate WTMD Procedure

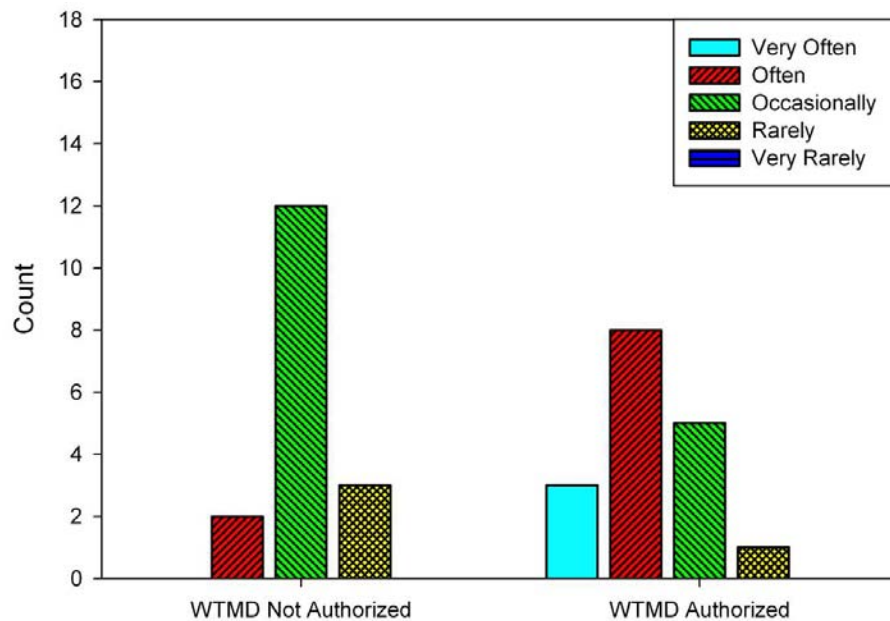


Figure 10. Supervisors' Anticipated Requirements for Monitoring WTMD Information With and Without WTMD Authorized

Lastly, subjects indicated that determining the appropriate runway on which to enable the WTMD procedure was easy (Appendix G – question 11) (Fig. 11).

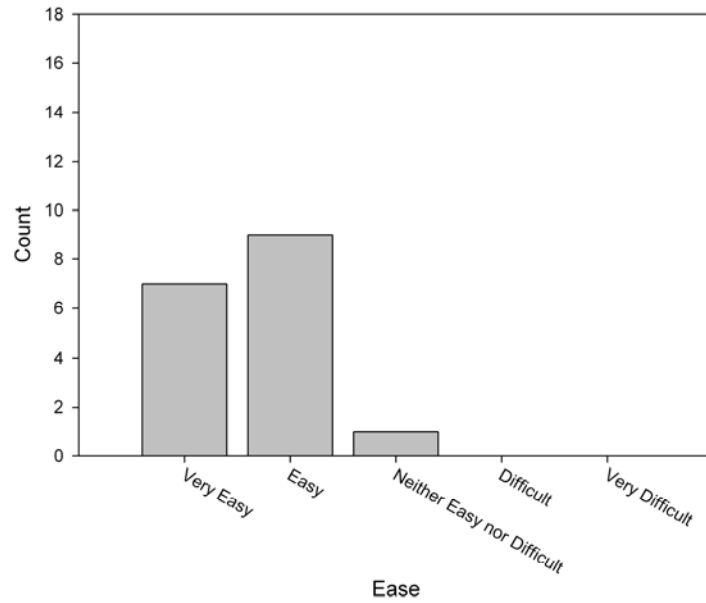


Figure 11. Ease of Determining Appropriate Runway on which to Enable WTMD Procedure On

Procedural Considerations

Supervisors felt that the WTMD procedure would be very effective during sustained departure demand. Even during low departure demand, supervisors commented that the WTMD procedure would be effective (Appendix G – question 14) (Fig. 12).

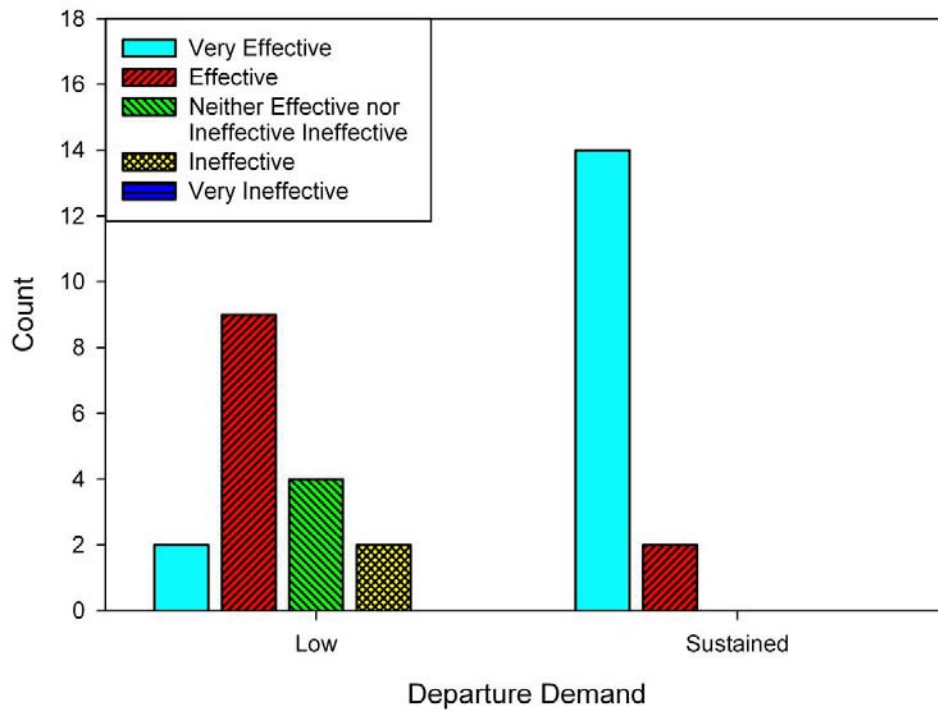


Figure 12. Perceived Effectiveness of WTMD Procedure During Low and Sustained Departure Demand

Subjects indicated that silencing the WTMD aural alarm should primarily be a function for the supervisor position (Appendix G – question 20) (Table 1).

Table 1. Positions Able to Silence a WTMD Aural Alarm

Position	Count
Supervisor	17
Controller-in-Charge	10
Local controller on the WTMD enabled runway	8
Local controller on the non-WTMD enabled runway	5
Other controller	0

Summary of Questionnaire Results

The nominal questionnaire responses from IAH and STL, each with different parallel runway operations, did not vary significantly. Therefore, it is possible that the results from these two facilities may generalize to other facilities with parallel runway operations.

Overall, the results indicated that supervisors judged that the WTMD procedure and the information provided to them about its status were adequate. Supervisors felt that they would not have to modify their personal behaviors significantly, except for adding the monitoring of the WTMD-procedure status and possibly increasing the frequency of looking at the ITWS display.

Supervisors did indicate a desire to know the history of the WTMD-procedure status and why the WTMD procedure is no longer authorized (when that is the case). They stated that knowledge of the status history would affect their willingness to enable/authorize the WTMD procedure. Not surprisingly, supervisors felt they should have primary control of WTMD-related alarms.

Supervisors felt the WTMD procedure would benefit departure operations, even during low departure demand.

The survey results of ATC supervisors indicated that the WTMD procedure and its related displays are sufficient for supervisors to enable/authorize and disable/terminate the WTMD procedure.

The WTMD procedure may benefit all parallel runway operations by decreasing overall delays at the airport at which it is in use. But before this procedure is implemented, further human-in-the-loop testing is needed to confirm these supervisors' opinions.

7.3 General Comments from Subjects

Perception of the WTMD procedure. All subjects felt that the procedure was simple, easy to understand and would require minimal training to apply at their respective facilities. (This finding was underscored by the minimal exposure to the concept required for this research, after which subjects were able to provide useful and insightful comments.) It was also felt by all subjects that they would feel comfortable authorizing use of the procedure. As noted in the previous section, supervisors felt that they would not have to modify their behavior significantly to support the procedure.

Value of WTMD procedure. Subjects universally reported that there was clear value for the WTMD procedure. This response includes subjects from STL, which has experienced reduced traffic volume in recent years. All except for two of the seventeen subjects said that they would authorize use of the procedure even if it were of benefit to only one or two aircraft.

How the procedure would be used. Unsolicited comments from five subjects indicated that controllers could actively assign aircraft to runways according to aircraft weight category, to maximize benefits from use of the procedure. (Note that the initial WTMD concept does not anticipate wake category-related runway assignment of aircraft to maximize use of the procedure.) There was also consensus that the WTMD procedure would provide additional latitude in conducting operations in several common situations (e.g. not missing opportunities to depart aircraft between arrivals because of having to delay behind B757 or Heavy aircraft off the downwind runway).

Requirements for using the WTMD procedure. Subjects generally agreed that use of the WTMD procedure would require several actions including coordination with air traffic personnel in the ATCT, and coordination with other appropriate air traffic and airline organizations (e.g. TRACON, Center, Air Traffic Control System Command Center (ATCSCC), and Airline Operations Centers). The Automatic Terminal Information Service (ATIS) broadcast should be updated to reflect the use of the WTMD procedure including the affected runways. An entry in the facility log should be required to indicate the time the procedure was authorized for use and when it was terminated. Finally, a checklist might be useful to ensure all required actions are taken.

Alerting. The issue of “alerting” in the context of drawing attention to changes in the status of the WTMD system prompted varied comments. The single comment echoed by most subjects was that there are currently too many alarms. (One subject identified six different alarms that currently exist in the tower.) The vast majority of all subjects agreed that some form of alerting was required to indicate changes in status of the WTMD system. The audio and visual interface needs to be designed to be compatible with other tower systems. Supervisors mentioned that appropriate alerting and alarm functionality that minimizes nuisance or false alarms is required. Supervisors judged the combination of visual and audio alert to be important, but there was universal concern that it should not be implemented as a system that conflicts with other tower cab system alerts that could create unnecessary confusion and increase in workload.

Access to information supporting WTMD operations. There was consistency among the subjects regarding the type of information that was accessed for day-to-day operations (weather, traffic loading, flow restrictions, etc.), the priority of accessing that information, and information that would be accessed during use of the procedure.

Training Requirements. Results indicate that WTMD training could be conducted in a reasonably short session that would include classroom training of the concept and WTMD systems and local procedure. Subjective feedback indicated that supervisors would incorporate the WTMD system with other decision-making tools and information in the tower cab, so training of the WTMD procedure could be a module in the supervisor or controller in charge certification. Hands-on training with a simulation or system mockup may also be helpful to provide controllers and supervisors adequate preparation for using the WTMD system.

WTMD Display/Interface. Results indicate that the WTMD status information needs to be hosted on an “appropriate” display in the tower cab, and supervisors indicated this should be situated near the wind and altimeter status displays. WTMD status information is safety critical, so it would need to have system reliability, integrity, and availability for a flight critical display. Supervisors were confident the system would be certified to these standards prior to implementation. Some subject comments mentioned that repeating WTMD information into the TRACON may also prove useful, but this facility level (TRACON) coordination was not a focus of the current effort. While the WTMD prototype display included both runway ends independently, several supervisors desired the display to include one status for both runway ends, e.g., “15L/33R Available,” since WTMD does not control which runway is active, but uses a runway already declared active.

8.0 Concluding Remarks

Results indicated that the following information was required to support the conduct of WTMD operations: current and forecast weather information, current and forecast traffic demand and traffic flow restrictions, and WTMD System status information and alerting.

The WTMD procedure offers the potential to significantly improve airport efficiency. Central to the implementation of WTMD is acceptance by the ATCT supervisor or controller-in-charge who would authorize its use. Part of this acceptance is ensuring that the necessary information is available by those authorizing the procedure. This data collection activity identifies that information. In the process of collecting that data, information in other areas relating to WTMD was captured and is included in the results.

Two WTMD prototypes were developed that placed WTMD status information onto a display accessible to the supervisor – the STL prototype had WTMD information on the ACE-IDS, and the IAH prototype had WTMD information on the IDS-4. The general supervisor acceptability of these prototypes demonstrated that WTMD information can be displayed on platforms suitable to a candidate airport's ATCT equipment. Specific WTMD architecture and display designs should be considered by trade study.

Both quantitative questionnaire data and comments recorded from interviews were consistently favorable to the WTMD concept and supporting procedure. All subjects felt that the WTMD procedure offered operational benefits, even in low demand periods, and could be easily applied at their respective facilities. All subjects also felt that the information necessary to support the procedure was currently accessible in their respective facilities. They further felt that it would take minimal training time to understand WTMD and to feel comfortable with the process of authorizing, monitoring, and terminating the WTMD procedure. Supervisor subjects indicated that using the WTMD procedure would not significantly change their behavior, including the displays they would usually use in the course of performing normal duties. The manner in which “alerting” was provided for changes in the WTMD status was of concern among most subjects and requires further research. There was general agreement among the subjects that historical data concerning the WTMD status would be useful and would affect their willingness to authorize the procedure. Finally, there was consensus that authorization to use the WTMD procedure would require certain actions. Examples include updating the ATIS broadcast to indicate the use of WTMD Operations, coordinating with other ATCT and adjacent facilities, making a log entry, among possibly others.

9.0 References

1. FAA, February 2006, *Air Traffic Control*, FAA Order 7110.65R, Federal Aviation Administration, Washington, D.C.
2. Lang, Steve, J. Tittsworth, C. Lunsford, W. Cooper, L. Audenaerd, R. Cole, May 2005, *An Analysis of Potential Capacity Enhancements Through Wind Dependent Wake Turbulence Procedures*. Federal Aviation Administration, Washington D.C.
3. Lunsford, C. R., P. Moertl, J. Tittsworth, November 2005, *Initial Concept of Use for Closely Spaced Parallel Runways (CSPR) Wind- Dependent Departures*, MP 05W0000285,. The MITRE Corporation, McLean, Virginia.
4. Mundra, Anand, C. Lunsford, A. Oswald, L. Ross, March 2005, Presentation: *Preliminary Results from the Simulations for Proposed CSPR Wind Dependent Departure Procedure*, The MITRE Corporation, McLean, Virginia.
5. Domino, David A., C. Lunsford, P. Moertl, A. Oswald, May 2006, Controller Assessment of Procedures for Wake Turbulence Mitigation for Departures (WTMD) from Closely Spaced Parallel Runways, MP 06W0000102, The MITRE Corporation, McLean, Virginia.

Appendix A - STL WTMD SYSTEM INSTALLATION

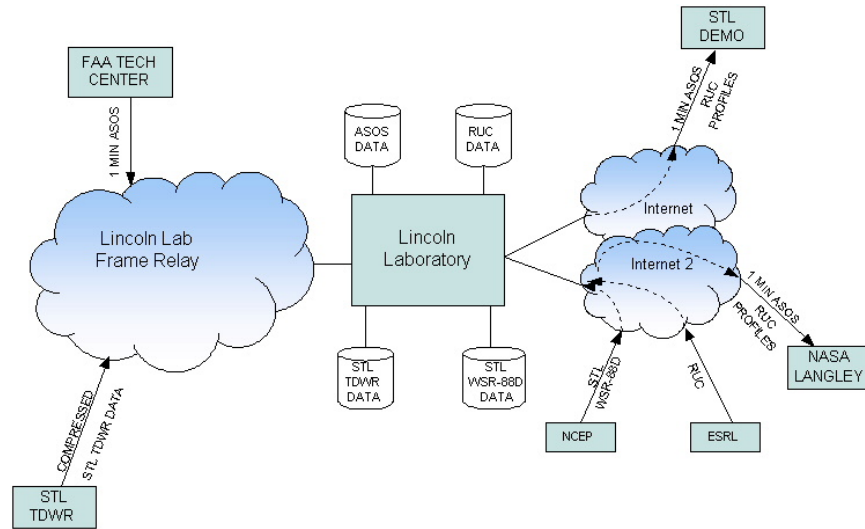


Figure A.1 Overview of STL WTMD Network Architecture

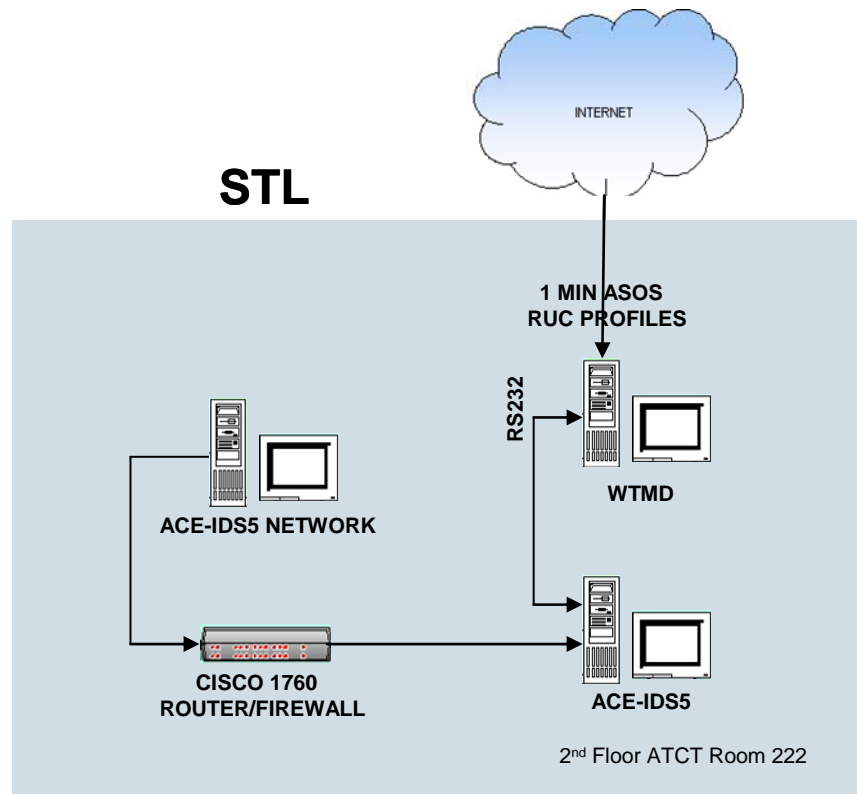


Figure A.2 STL WTMD Prototype Hardware

Appendix B - AIRPORT DIAGRAM – LAMBERT-ST. LOUIS INTERNATIONAL AIRPORT

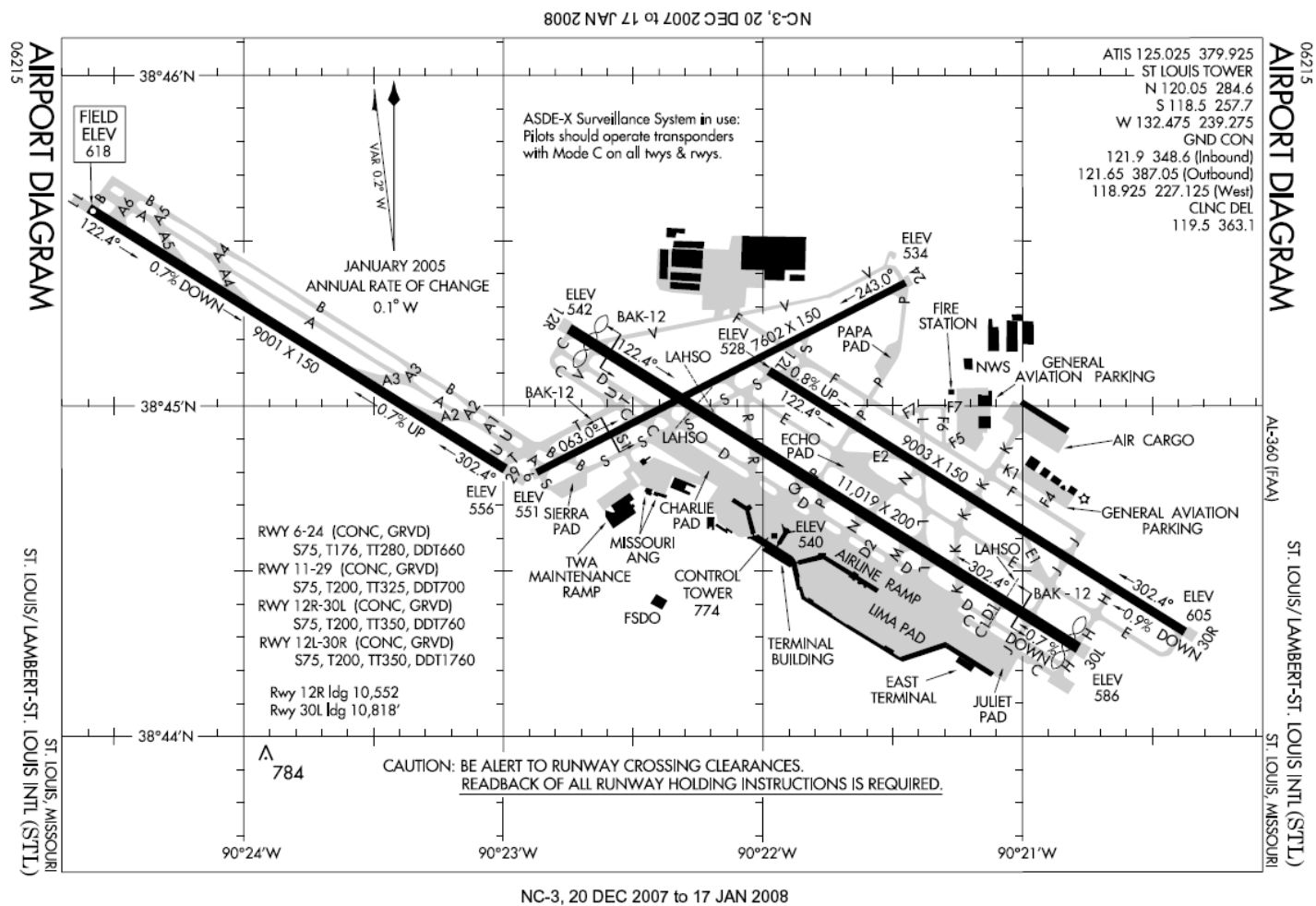


Figure B.1 Airport Diagram – Lambert-St. Louis International Airport

Appendix C - IAH WTMD SYSTEM INSTALLATION

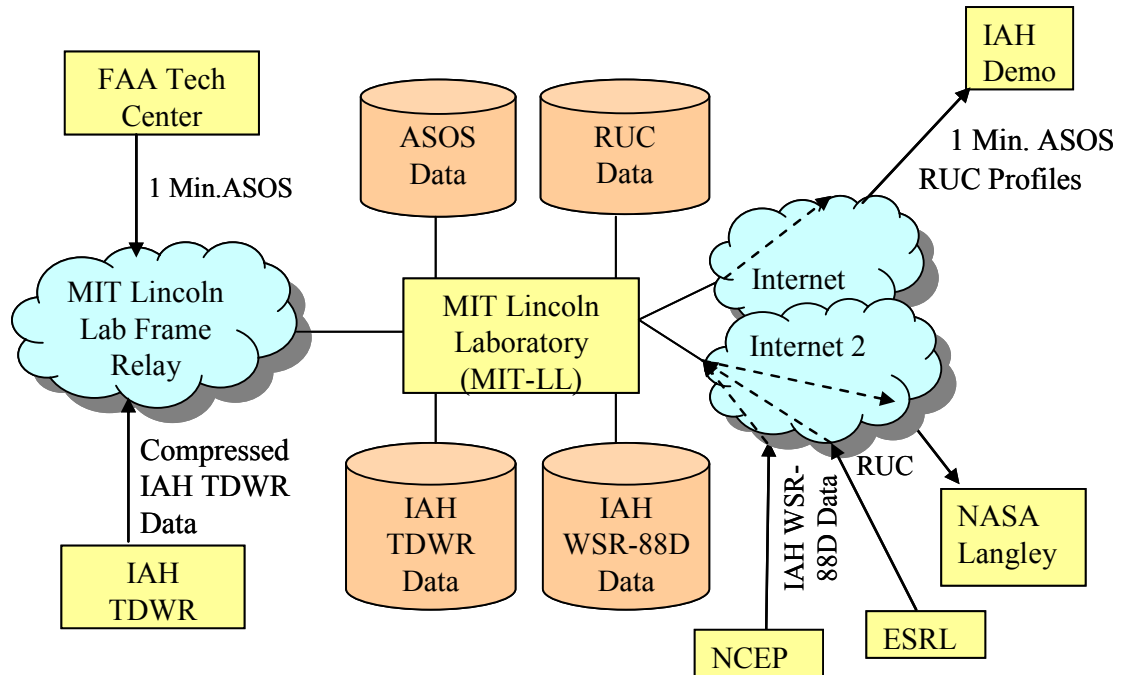


Figure C.1 Overview of IAH WTMD Network Architecture

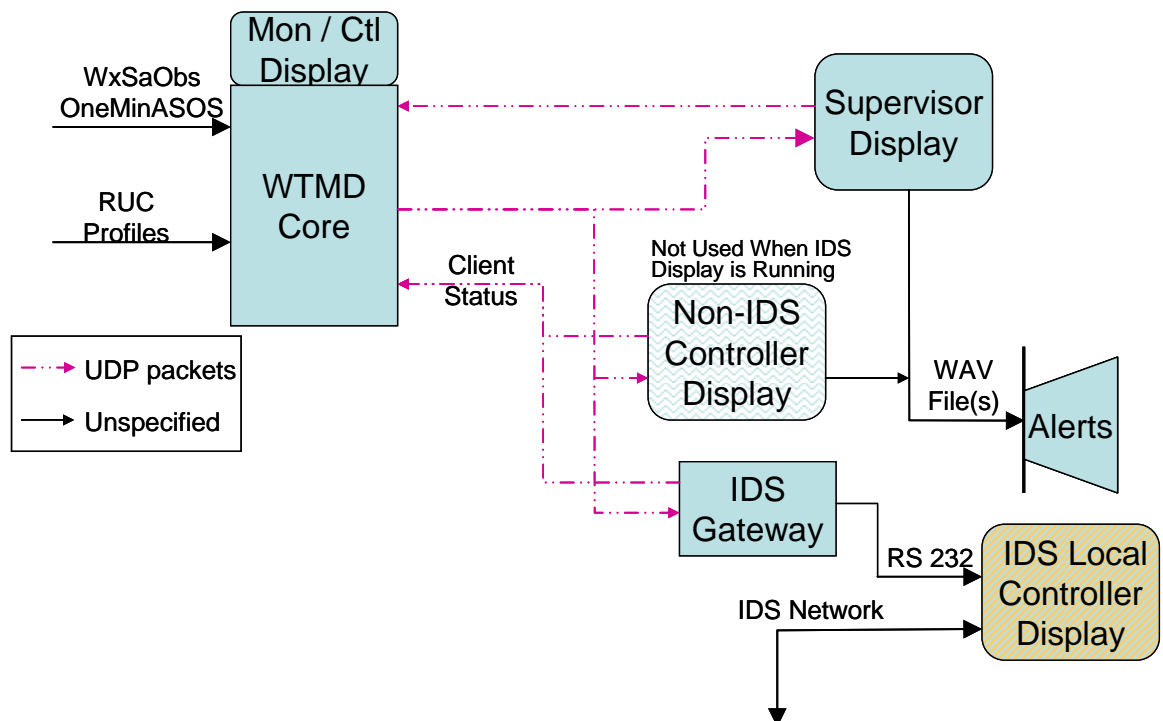


Figure C.2 IAH WTMD Shadow Mode Field Prototype Architecture

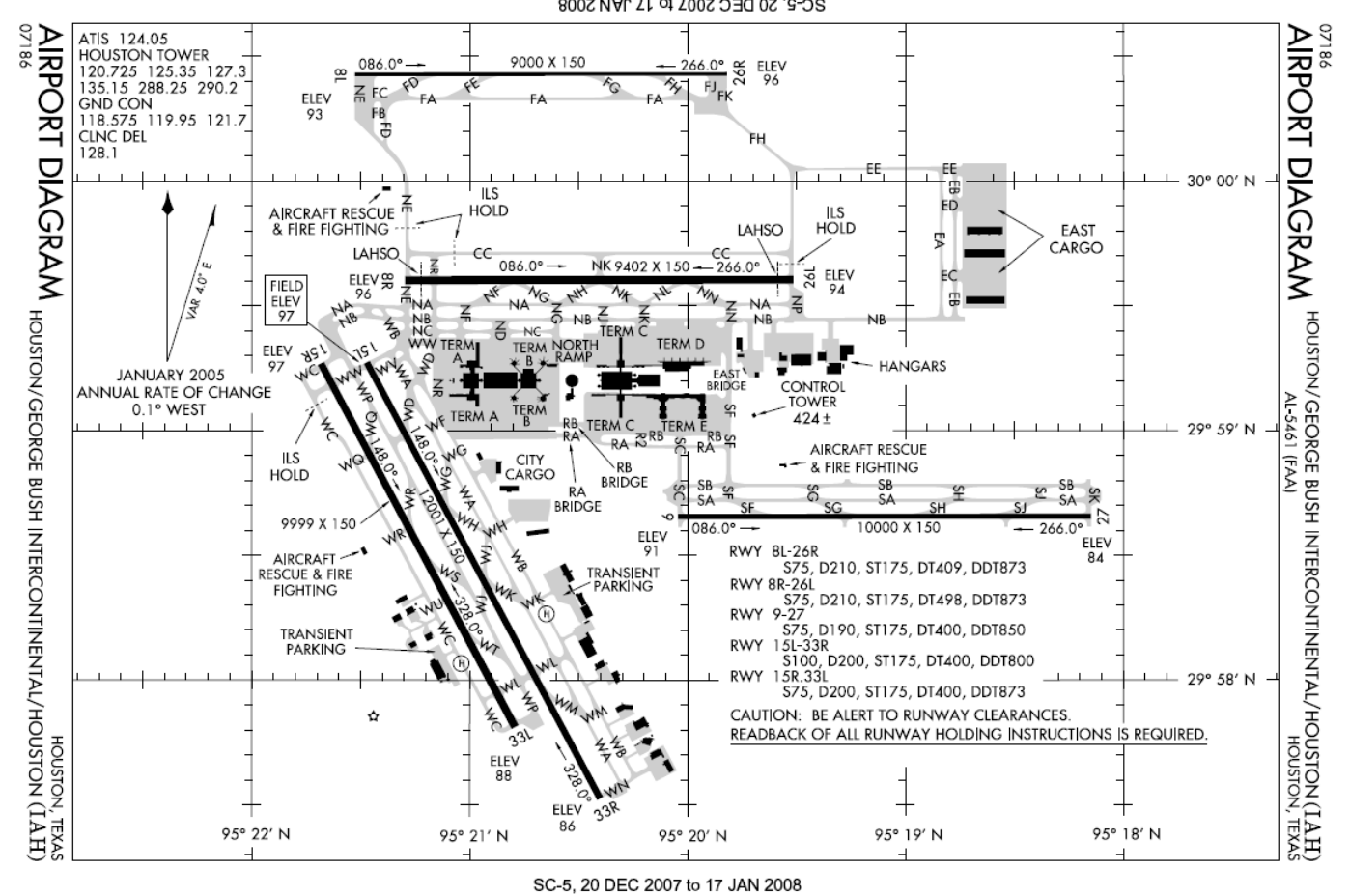


Figure D.1 Airport Diagram – George Bush Intercontinental/Houston Airport

Appendix E – SAMPLE SCENARIO

Airport Configuration - Arriving 8L/R, Departing 15L/R

Airport Arrival Rate: 60/hr

Flow restrictions: None

Winds: 100/9

Weather: visual meteorological conditions; clear throughout terminal area.

Projected departure demand: 40/hr



Figure E.1 IAH WTMD Status Display

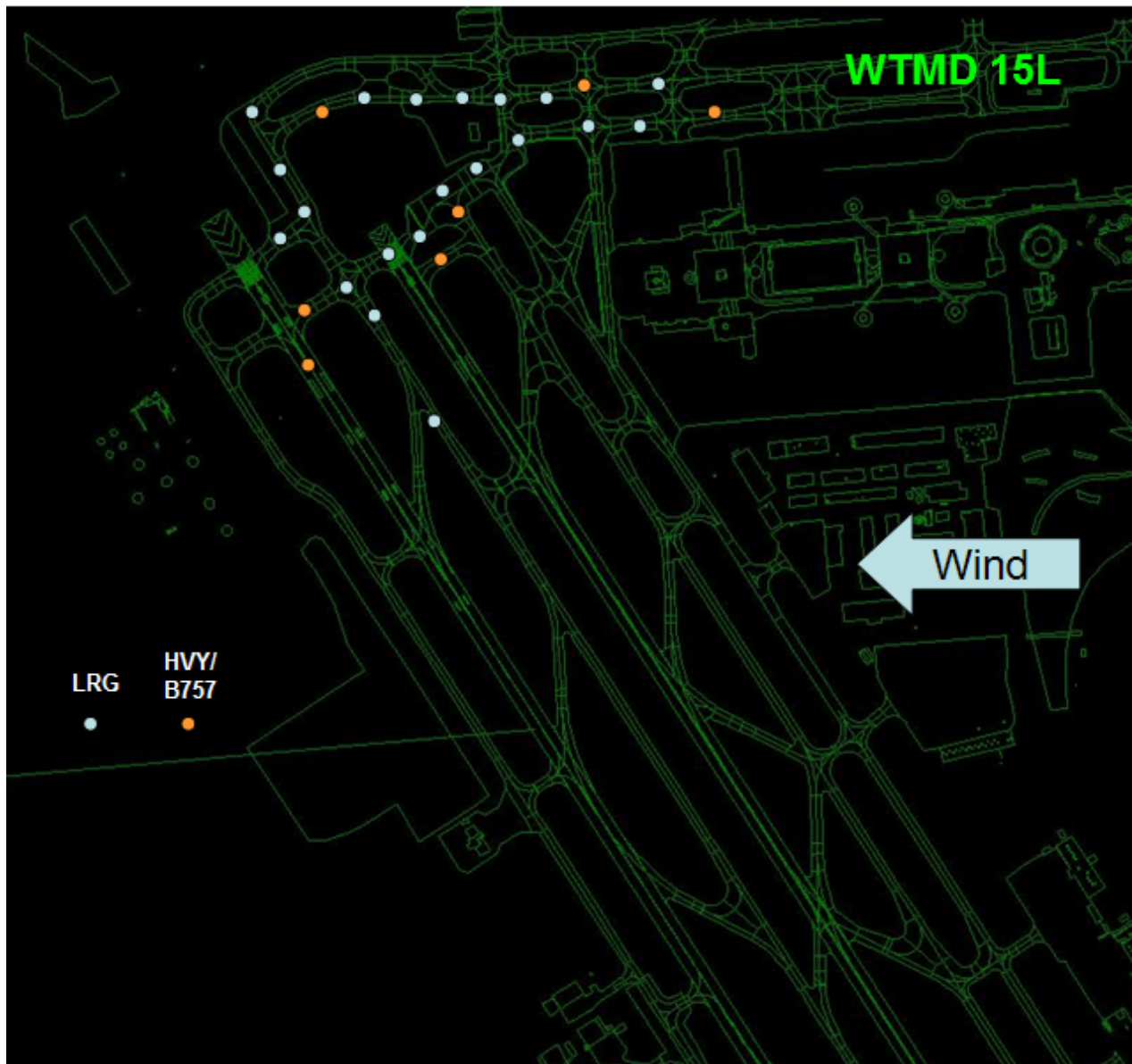


Figure E.2 IAH Sample ASDE

Appendix F – POST SCENARIO INTERVIEW GUIDE

Assuming the WTMD system indicated that a runway could be operated wake independently, would you authorize the WTMD procedure regardless of any other factors (e.g. traffic loading, weather, flow restrictions, etc.)?

Do you feel that all the information needed to determine whether or not to authorize the WTMD procedure? If not, what additional information do you feel is needed.

What priority do you assess to the factors you feel enter into the decision making process regarding the authorization and termination of the WTMD procedure?

What process would you use in determining whether to authorize or terminate the procedure? (If primer needed: e.g. 1) consider airport configuration, 2) determine traffic loading, 3) look at wind forecast, 4) etc.

What process would you use in determining whether to authorize or terminate the procedure? (If primer needed: e.g. 1) consider airport configuration, 2) determine traffic loading, 3) look at wind forecast, 4) etc.

Assuming you have authorized the WTMD procedure, do you feel you would need to monitor the operation, even with alerting provided by the WTMD system that would advise of a System failure? (Recall that this alerting is available to the local controller.)

Candidate WTMD Checklist	
Factors	Contact:
Current Traffic Loading	Tower personnel
Anticipated demand	TRACON
Runway Usage	ARTCC
Airport configuration	If applicable, ATCSCC
Ground flow constraints	
Weather - Convective	Log entry
Local Flow restriction	
External flow restrictions	

Appendix G – QUESTIONNAIRE

Thank you for providing us your inputs on the WTMD procedure. For the following multiple choice questions, please mark the appropriate circle.

All participation is voluntary. You are free to withdraw at any time without penalty or loss of benefits otherwise available to you. Furthermore, you are free not to answer any questions that you choose without penalty.

As before, any information you provide will be kept in strict confidence to protect your privacy. No personal data that you provide will be released in any form and your data will be keyed only to a test subject number.

Operational means the WTMD system is receiving valid data.

Failed means the WTMD system is not receiving valid data.

Available means the WTMD procedure could be enabled for use on a particular runway.

Off means the WTMD procedure is not available for use on a particular runway.

Enable means the WTMD procedure could be approved for use for a particular runway.

Disable means the WTMD procedure could be stopped for a particular runway.

Authorized for use means the supervisor has approved the use of the WTMD procedure.

Terminated the use of means the supervisor has ended the use of the WTMD procedure.

Status means the state of the WTMD procedure; operational, failed, available, off, and runway with the enabled WTMD procedure.

If you have any questions about the WTMD procedure, the questionnaire, or would like to be notified of the results, please feel free to contact:

Gary Lohr	(757) 864-2020 Gary.Lohr@nasa.gov
Dan Williams	(757) 864-3096 Daniel.M.Williams@nasa.gov
Anna Trujillo	(757) 864-8047 Anna.C.Trujillo@nasa.gov

Thank you for your participation.

STL Air Traffic Control Tower Supervisor Assessment of the WTMD Procedure

General

1. The content of the training on the WTMD procedure was adequate.

<input type="radio"/> Strongly Agree
<input type="radio"/> Agree
<input type="radio"/> Neither Agree nor Disagree
<input type="radio"/> Disagree
<input type="radio"/> Strongly Disagree

2. As a supervisor (when not working traffic), the displays I normally look at are:

Display	Frequently	Occasionally	Rarely
ASDE-X	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D-BRITE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ACE-IDS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ITWS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 1.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 2.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 3.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. When working as a supervisor, would an *enabled* WTMD procedure cause you to change the displays you normally look at?

☐ Yes ☐ No

If YES, please indicate changes from question:

Display	More Often	Same	Less Often
ASDE-X	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D-BRITE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ACE-IDS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ITWS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 1.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 2.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 3.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4. The *information* for determining the status of the WTMD procedure is sufficient.

<input type="radio"/> Strongly Agree
<input type="radio"/> Agree
<input type="radio"/> Neither Agree nor Disagree
<input type="radio"/> Disagree
<input type="radio"/> Strongly Disagree

5. I estimate that I will need to monitor the WTMD status information while the WTMD procedure is *authorized* for use:

<input type="radio"/> Very Often
<input type="radio"/> Often
<input type="radio"/> Occasionally
<input type="radio"/> Rarely
<input type="radio"/> Very Rarely

6. I estimate that I will need to monitor the WTMD status information while the WTMD procedure is not *authorized* for use:

<input type="radio"/> Very Often
<input type="radio"/> Often
<input type="radio"/> Occasionally
<input type="radio"/> Rarely
<input type="radio"/> Very Rarely

7. Who else *in the tower*, besides the local controllers, needs to be notified of the status of the WTMD procedure and why?

8. What other air traffic facilities/entities (*e.g.*, AOCs, TRACONs, etc.) should be notified of the status of the WTMD procedure and why?

Enabling and Authorizing the WTMD Procedure

9. I am confident that I would have access to the information I need to enable and authorize the use of the WTMD procedure.

<input type="radio"/> Strongly Agree
<input type="radio"/> Agree
<input type="radio"/> Neither Agree nor Disagree
<input type="radio"/> Disagree
<input type="radio"/> Strongly Disagree

What other information is required?

10. Obtaining information about whether to enable and authorize the use of the WTMD procedure would be:

<input type="radio"/> Very Easy
<input type="radio"/> Easy
<input type="radio"/> Neither Easy nor Difficult
<input type="radio"/> Difficult
<input type="radio"/> Very Difficult

11. Determining the appropriate runway to enable for the WTMD procedure would be:

<input type="radio"/> Very Easy
<input type="radio"/> Easy
<input type="radio"/> Neither Easy nor Difficult
<input type="radio"/> Difficult
<input type="radio"/> Very Difficult

12. I estimate that the past history of the status of the WTMD procedure would be:

<input type="radio"/> Very Helpful
<input type="radio"/> Helpful
<input type="radio"/> Neither Helpful nor Unhelpful
<input type="radio"/> Unhelpful
<input type="radio"/> Very Unhelpful

Would this past history of the status of the WTMD procedure affect your willingness to enable and authorize the WTMD procedure?

☐ Yes ☐ No

13. I would be confident in enabling and authorizing the use of the WTMD procedure with the amount of information given:

<input type="radio"/> Strongly Agree
<input type="radio"/> Agree
<input type="radio"/> Neither Agree nor Disagree
<input type="radio"/> Disagree
<input type="radio"/> Strongly Disagree

14. How effective would the WTMD procedure be during periods of:

	Very Effective	Effective	Neither Effective nor Ineffective	Ineffective	Very Ineffective
low departure demand?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
sustained departure demand?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. List some reasons why you may *not* enable and authorize the WTMD procedure even when the system indicates that it is available.

16. In addition to the WTMD system state display, which displays would be the most effective in deciding to enable and authorize the use of the WTMD procedure?

Display	Very Effective	Effective	Neither Effective nor Ineffective	Ineffective	Very Ineffective
ASDE-X	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D-BRITE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ACE-IDS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ITWS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 1.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 2.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 3.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Disabling and Terminating the WTMD Procedure

17. I am confident that I would have access to the information I need to disable and terminate the use of the WTMD procedure.

<input type="radio"/> Strongly Agree
<input type="radio"/> Agree
<input type="radio"/> Neither Agree nor Disagree
<input type="radio"/> Disagree
<input type="radio"/> Strongly Disagree

What other information is required?

18. Obtaining information about whether to disable and terminate the use of the WTMD procedure would be:

<input type="radio"/> Very Easy
<input type="radio"/> Easy
<input type="radio"/> Neither Easy nor Difficult
<input type="radio"/> Difficult
<input type="radio"/> Very Difficult

19. I would be confident in terminating the use of the WTMD procedure with the amount of information given.

<input type="radio"/> Strongly Agree
<input type="radio"/> Agree
<input type="radio"/> Neither Agree nor Disagree
<input type="radio"/> Disagree
<input type="radio"/> Strongly Disagree

20. Who should be able to silence a WTMD aural alarm across all stations? (check all that apply)

- ☐ Supervisor
- ☐ Local controller on the non-WTMD enabled runway
- ☐ Local controller on the WTMD enabled runway

21. As a supervisor, would you want to know why the WTMD procedure became unavailable?

- ☐ Yes ☐ No

Why

22. Which displays would be the most effective in deciding to disable and terminate the use of the WTMD procedure?

Display	Very Effective	Effective	Neither Effective nor Ineffective	Ineffective	Very Ineffective
ASDE-X	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D-BRITE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ACE-IDS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ITWS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 1.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 2.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other 3.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other Comments:

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14. ABSTRACT A concept focusing on wind dependent departure operations has been developed the current version of this concept is called the Wake Turbulence Mitigation for Departures (WTMD). This concept takes advantage the fact that cross winds of sufficient velocity blow wakes generated by "heavy" and B757 category aircraft on the downwind runway away from the upwind runway. Supervisory Air Traffic Controllers would be responsible for authorization of the Procedure. An investigation of the information requirements necessary to for Supervisors to approve monitor and terminate the Procedure was conducted. Results clearly indicated that the requisite information is currently available in air traffic control towers and that additional information was not required.						
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